North Carolina
Department of
Transportation

Chapter 11
Roadside Ditches and Channels

January 2022

Revisions Sheet			
Page	**Old Section**	**New Section**	**Description**
-	-	-	• Entire Chapter revised to new format and minor grammatical changes made throughout • All references and links have been updated throughout Chapter
1	11.1	11.1	Revised section heading to Introduction
3	11.2.5	11.2.5	• 1st paragraph revised • Removed 2nd and 3rd paragraphs • 3rd and 5th paragraphs revised
4	11.3	11.3	4th sentence revised to change document title of “Guidelines for Mountain Stream Relocation in North Carolina.”
4 - 5	11.3	11.3	4th sentence replaced NCDEQ Stream Mitigation Guidelines and Stream Restoration, A Natural Channel Design Handbook with updated documents.
5	11.3.1	11.3.1	Last sentence revised: Replaced reference to Appendix J with FHWA HEC-15
9	-	11.4	Added new section - References
11	-	11.5	Added new section – Additional Documentation
11	Appendix M	11.5	Added Stream Relocation Guidelines

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11.1 Introduction

A channel is a conveyance in which water flows with a free surface. It may be natural or manmade. A roadside ditch is a manmade channel that parallels the roadway surface and is distinguished by a regular geometric shape. The design process and analysis requirements differ for roadside ditches and channels. Roadside ditches are roadside and median drainage conveyances that carry surface stormwater away from roads and subgrade drains.

This chapter defines a channel as any open conveyance facility not classified as a roadside ditch or requiring more than a two-foot-wide base. This chapter addresses specific criteria and analysis requirements, with general design procedures presented. For more detailed design guidance, refer to FHWA's HEC-23 (FHWA 2009), HEC-14 (FHWA, P.L. Thompson, R.T. Kilgore (Authors) 2006), HEC-15 (FHWA, R.T. Kilgore, G.K. Cotton (Authors) 2005), Chapter 6 of the *AASHTO Highway Drainage Guidelines* (AASHTO 2007), and Chapter 10 of the *AASHTO Drainage Manual* (AASHTO 2014).

11.2 Roadside Ditches

11.2.1 Establishment of Ditch Plan

Establish a ditch plan to show the proposed ditch locations and flow patterns. This ditch plan is a part of the drainage plan (Chapter 5, Section 5.3.1 – item 8).

11.2.2 Determination of Typical Ditch Cross Section

Determine the standard or typical ditch cross sections for the project, which are provided by the roadway plans typical sections. When a ditch is required along the construction limits and is not shown in the roadway typical section, the following criteria should be followed in establishing a typical section:

- Specify a standard berm ditch section at the top of a cut section where required, as depicted in Roadway Standard Drawing 240.01 (NCDOT 2018). If it is necessary to bring water down cut slopes into the highway drainage system when the roadway grade is at a lower elevation than the natural drain which it crosses, it may be necessary to intercept runoff from the berm ditch into a berm drainage outlet, as depicted in Roadway Standard Drawing 850.10-11 (NCDOT 2018), to convey the runoff from the top of the cut slope to a storm drain inlet located in the typical roadway cut ditch. Safety bars over the pipe opening may be warranted in neighborhoods for the safety of small children.

- Form toe of fill ditches adjacent to shallow fills and flat slopes (4:1 or flatter) by continuing the fill slope to a desired ditch depth, providing a base width, if required, then a stable back slope (2:1 minimum).
- Construct toe of fill ditches adjacent to high steep slopes with at least a two-foot berm (five-foot preferred). A wider berm is desirable for very high fills to prevent embankment from filling the ditch and for maintenance if access is limited from opposite the roadway side.

11.2.3 Determination of Ditch Gradient

Determine the gradients to be used on all proposed ditches. Roadside ditches included in the typical roadway section will have a grade corresponding to the roadway profile. When the roadway profile grade is less than 0.3%, establish special roadway ditch grades and note them on the plans. Ditches along the toe of fill will generally parallel the grade of the natural ground at an established acceptable depth. Establish and plot ditch grades on the roadway plans in the profile view.

11.2.4 Investigation of Ditch Capacity

Design roadside ditches, including temporary detour ditches, to contain the Q_{10} discharge at a minimum. Establish the typical roadside ditch section with sufficient depth to drain the pavement subbase and provide flat side slopes for safe vehicle maneuverability. This generally provides very generous capacity for the design flow requirements. Evaluate actual capacity determination on a selective basis at sites on common project grades to verify adequacy and establish limitations on the length of ditch run. Account for any likelihood of future pavement widening toward the median in the median ditch drainage analysis and design. Size driveway pipes in ditches to convey the same design discharge as that for which the ditch is designed.

Establish the size requirements of the project special side ditches along the toes of fill based on an analysis of the design flood. Perform this ditch capacity using Manning's equation: $Q = (1.49/n)\ A(R^{2/3})\ (S^{1/2})$, where Q is discharge in cubic feet per second (cfs), A is flow area in square feet, S is slope (feet of fall per feet of length), and R is the hydraulic radius in feet.

Discharge determination shall follow the requirements of Chapter 7 - Hydrology. Consider the roadway section including shoulders and slopes to be an urban watershed. This capacity analysis is usually completed in conjunction with the next step of lining evaluation.

11.2.5 Evaluation of Ditch Lining for Stability

Analyze the stability of vegetative ditch linings by using FHWA HEC-15 (FHWA, R.T. Kilgore, G.K. Cotton (Authors) 2005) procedures, which determine the acceptability of given lining type by comparing the maximum shear stress of the flow to the permissible shear stress of the lining.

The maximum shear stress of the flow in a ditch can be established by the following equation:

$$\tau_d = \gamma d S_o$$

Where,

- τ_d is the maximum shear stress of the flow (lb./ft^2).
- γ is the unit weight of water (lb/ft^3). (Typically, 62.4 lb/ft^3)
- d is the depth of flow (ft)
- S_o is the channel longitudinal slope (ft/ft)

Grass-lined ditches tend to become unstable when flow velocity approaches 4.5 ft/sec or greater, requiring a non-vegetative liner to maintain stability.

Table 1 lists permissible shear stress values for typical non-vegetative ditch liners used by NCDOT:

Table 1. Permissible Shear Stress

Liner	d50 (in)	τ_p (lb/ft^2)
Class A riprap	4	1.6
Class B riprap	8	3.2
Class I riprap	10	4.0
Class II riprap	12	4.8

Another channel liner used by NCDOT is Permanent Soil Reinforcement Matting (PSRM), which is a synthetic geotextile product typically used for permanent erosion control or in conjunction with certain stormwater control devices, as specified in the Stormwater Best Management Practices Toolbox (NCDOT 2014). PSRM should not typically be specified as the primary liner for a roadside ditch or channel. However, it may be specified as an alternative liner where riprap may not be acceptable, such as within the clear recovery zone or in a homeowner's front yard. Its use should be clearly detailed to show that the matting serves as a reinforcement for the root system, and not on the surface with the vegetation trying to grow up through it. PSRM has a permissible shear stress of 3 lb/ft^2.

Specify type and dimensions of ditch liner in the ditch details shown in the plans. Roadway Standard Drawings 876.01-04 (NCDOT 2018) depict standards for rip rap placement in channels, drainage ditches, and at pipe outlets. For concrete ditch behind a retaining wall, note that the Geotechnical Unit has established standard cells and details which must be included, as applicable, in the design plans. (https://connect.ncdot.gov/resources/Geological/Pages/Geotech_Forms_Details.aspx)

11.2.6 Analysis of Ditch Outlet

Determine any special measures that may be required to mitigate or avoid scour or degradation at or downstream of the ditch outlet. Check the transition of flow from a ditch to the receiving outlet.

Factors to be considered:

- Is there provision for a smooth transition of flow from the ditch to the outlet?
- Will the outlet adequately handle the quantity of flow? Is improvement required?
- Is the velocity of flow at the outlet too high for the condition of the receiving channel? Is rip rap or other means of energy dissipation justified? (Refer to Chapter 10, Section 10.5.3.)
- When the receiving outlet is sheet overland flow, is concentration of flow by the ditch a potential problem? Is some form of flow diffusion required?
- Is access to the outlet provided for inspection and maintenance?

11.3 Channels

Channel analysis differs from roadway ditch analysis in that it involves establishing a channel configuration to meet specific site hydrologic and geomorphic requirements. The requirements for analysis can range from simple sizing of small ditches constructed adjacent to the roadway fill for interception and conveyance of discharge to acceptable outlets, to complex studies of extensive natural stream and river relocation. In addition to the guidance provided in this document, follow FHWA's Hydraulic Engineering Circular No. 15 (FHWA, R.T. Kilgore, G.K. Cotton (Authors) 2005) and Chapters 10 and 16 of the AASHTO *Drainage Manual* (AASHTO 2014), for further guidance for small ditch and channel analysis. For larger stream involvement, FHWA's *Highways in the River Environment* (FHWA, E.V. Richardson, D.B. Simons, P.F. Lagasse (Authors) 2001), *Applied River Morphology* (Rosgen 1996), NC Wildlife Resources Commission's *Guidelines for Mountain Stream Relocation in North Carolina* (NCWRC, P.J. Wingate, W.R. Bonner, R. J. Brown, B.M. Buff, J.H. Davies, J.H. Mickey, H.M. Ratledge (Authors) 1979), USACE's *Wilmington District Stream and Wetland Compensatory Mitigation Update* (USACE 2016), USACE's *Bank and ILF Establishment for All USACE Districts* (USACE n.d.), and USDA NRCS's *Stream Restoration Design (National Engineering Handbook*

654) (USDA NRCS 2007). Individual NCDOT Division offices may have established criteria for ditch and channel design which are applicable to construction practices within their own Divisions. Consult with the Division to ensure that appropriate and acceptable ditch and channel designs are specified and constructed.

11.3.1 Channel Lining for Stabilization

Rip rap lining may be needed to control erosion. A supplemental geotextile liner may be specified underneath the standard rip rap liner where warranted and should be shown and quantified in the ditch details and quantity estimates provided on the roadway plans. For channel capacity and stability analysis, follow the same guidance used for ditch design provided in Sections 11.2.4 and 11.2.5, using the design procedures in FHWA HEC-15 (FHWA, R.T. Kilgore, G.K. Cotton (Authors) 2005).

11.3.2 Realignment of Natural Channels

Design and configure the realignment of natural streams to match as near as practicable to the natural channel in alignment and gradient. Minimum disturbance to the natural flow is always the aim of good hydraulic design, except in areas where natural flow is unstable or detrimental, requiring restoration or mitigation measures, which can be incorporated in the highway drainage design.

For minor stream realignment at the inlet and outlet of structures (less than 100 feet total, approximately 50 feet each end), follow guidance provided in "Stream Relocation Guidelines" developed jointly by representatives of the NCDOT and the NC Wildlife Resources Commission in 1993 (See Section 11.5.1).

11.3.2.1 Morphological Stream Classification

If relocation of a stream channel is unavoidable, the design of the replacement channel should provide dimension, pattern and profile that affords natural stability. A process of stream classification developed by Dave Rosgen, detailed in *Applied River Morphology* (Rosgen 1996), has been widely used and accepted for effective analysis of natural streams and rivers. The objective of classifying streams on the basis of channel morphology is to set categories of discrete stream types, so that consistent, reproducible descriptions and assessments of conditions and potential can be developed.

Some specific objectives of a classification system include:

- providing a methodology for predicting a stream’s behavior from its appearance (classification)
- guiding development of specific hydraulic and sediment transport relationships for stream type and state
- comparing data for stream reaches having similar characteristics

- providing a consistent frame of reference for communicating stream conditions and morphology across disciplines

Follow the general guidance provided in the following sections when analyzing natural channels.

11.3.2.2 Data Collection for Stream Studies

Data collection includes office study as well as a field survey. Much of the information needed for initial classification can be obtained from topographic mapping and aerial photography. The field survey provides more detailed information for refining the initial classification as well as the analysis and design process.

At minimum, collect the following data:

11.3.2.2.1 Data Needed for Stream Classification

- channel width (bankfull)
- channel depth (section mean)
- maximum depth (at bankfull)
- bankfull cross section area
- slope (average for at least 20-30 channel width reach)
- stream length (20-30 bankfull channel widths in length)
- valley length (20-30 bankfull channel widths in length)
- bed material (type, size [D_{50}])
- bank material (type, size [D_{50}])
- width of flood-prone area

11.3.2.2.2 Data Needed for Stream Analysis and Design

- channel dimension
  - pool depth
  - pool width
  - pool area
  - riffle depth
  - riffle area
  - maximum pool depth
- channel pattern
  - meander length
  - amplitude
  - radius of curvature
  - belt width
- channel profile
  - valley slope
  - riffle slope
  - average water surface slope

- pool slope
- pool to pool spacing
- pool length

11.3.2.3 Establishment of Stream Type Classification

With the above data collected and further determination of stream features such as entrenchment ratio, width/depth ratio, and sinuosity, establish the stream type classification by following the procedure discussed in Chapter 3 of *Applied River Morphology* (Rosgen 1996).

11.3.2.4 Evaluation of Existing Conditions

Assess the existing stream condition as it relates to stability, state, and causes of changes, potential future impacts, and hydrologic and hydraulic requirements. This assessment process should address:

- the watershed
- flow regime
- riparian vegetation
- bank stability
- bed stability
- meander patterns
- sediment supply and transport
- debris
- aggradation/degradation
- aquatic and terrestrial habitat
- discharge levels and conveyance requirements
- evolutionary trend

Stream conditions gathered through the assessment process apply only to the reach of the stream studied and may vary considerably upstream and downstream as the character of the valley changes. Some stream study reaches may be at such an altered state that existing conditions data are of little value in developing recommendations for a relocated or restored channel. When this occurs, use a reference stream of similar classification and morphological characteristics as a guide to develop study proposals.

11.3.2.5 Developing and Documenting Proposed Channel Design

The above evaluation process should provide the Hydraulic Design Engineer with sufficient information and knowledge necessary to develop a recommended channel relocation or restoration proposal that meets hydrological and ecological requirements and provides a natural, stable system. Consult a wildlife resource specialist for input during the design process. Document all information pertinent to the channel design in an appropriate design report format.

11.4 References

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11.5 Additional Documentation

11.5.1 Minor Stream Relocation Guidance

Stream Relocation Guidelines

NOTE: These guidelines are for the piedmont and coastal regions. While these guidelines are similar to the trout county requirements, they do not replace the existing process for trout counties. This guidance is to be followed prior to the permit process to facilitate that process and to minimize impacts

"Minor Relocations"	"Standard Relocations"
Applicable when: - Less than 100 feet of total relocation is required at a given crossing (from the end of the structure, inluding headwalls), and no more than 50 feet is relocated on any one side (upstream or downstream)	**Applicable when:** - Greater than 100 feet of total relocation is required at a given crossing (from the end of the structure inlud-ing headwalls), Or more than 50 feet is relocated on any one side (upstream or downstream)
Technical guidelines: -Relocation should be similar to original channel in Width Depth Gradient Substrate -Bank vegetation should be re-established, but no specific planting regime is required	**Technical guidelines:** -Relocation should be similar to original channel in Width Depth Gradient Substrate For the following items, site specific requirements will be determined through coordination with the WRC field staff. These items will follow WRC's established guidelines and will incorporate any highway specific guidance jointly developed between WRC, Hydraulics, and Roadside Environmental: - Re-etablishment of bank vegetation with planting regime required - Meanders and habitat structures (root wads, wing deflectors, etc.) approximating the original stream
Co-ordination with WRC field staff: -No coordination is required unless in High Quality Waters(HQW), critical habitat(as mapped by WRC), or at locations involving Federal/State listed species. Treat these cases as "Standard Relocations". Note: WRC coordination will be welcomed even on "Minor"projects.	**Co-ordination with WRC field staff:** -Coordinate the relocation with the appropriate WRC district fisheries biologist

General Guidance: Minimize instream activities during peak spawning periods (April-June)
- Schedule instream activities during periods of low flow as much as possible
- Use vegetation to stabilize streambank vs. riprap to the maximum extent practicable
- Minimize use of fertilizer adjacent to stream
- Use native woody/shrub like species with small basal width within 25-50 ft. of the structure to reduce clog-ging. Beyond that distance use native tree species.
- It is preferred that bank vegetation be re-established prior to introducing flow into the channel.
- For reference utilize NC Wildlife Res. Comm. document "NC Stream Protection and Improvement Guide-lines"

NOTE: Coordination with WRC on projects covered by nationwide permits (outside the 25 trout counties) is voluntary. This is a proactive effort by NCDOT and WRC minimize habitat impacts from highway projects and to facilitate communication and understanding at the field level.